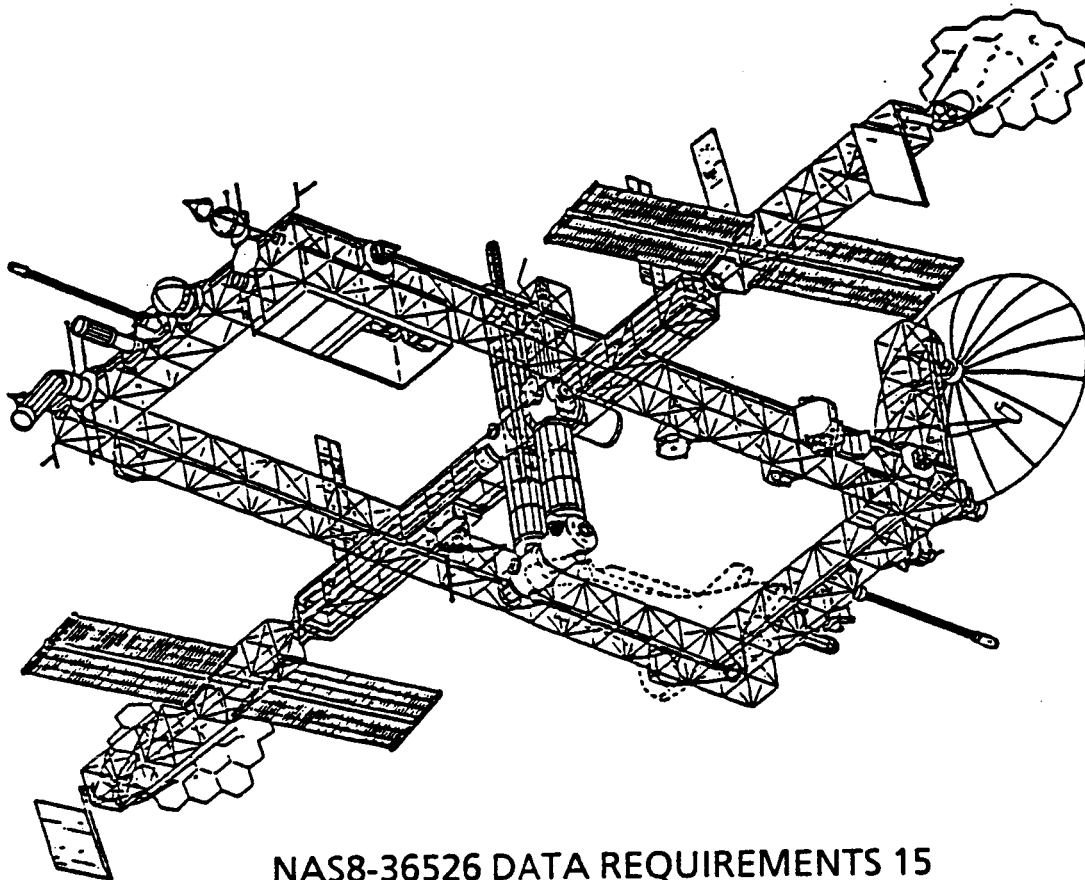


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# **BOEING**

# **Space Station**

WP01



NAS8-36526 DATA REQUIREMENTS 15

## **FINAL STUDY REPORT**

VOL I EXECUTIVE SUMMARY

JANUARY 18, 1987

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# FINAL STUDY REPORT

VOL I EXECUTIVE SUMMARY

JANUARY 18, 1987

CONTRACT NAS8-36526

Submitted to

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**FINAL STUDY REPORT**

**VOLUME I**

**EXECUTIVE SUMMARY**

## ***ABSTRACT***

Volume I, contained herein, of the Final Study Report provides an Executive Summary of the Phase B study effort conducted under contract NAS8-36526. Space Station Phase B implementation resulted in the timely establishment of preliminary design tasks, including trades and analyses. A comprehensive summary of project activities essential in conducting this study effort is included herein.

## **KEY WORDS**

Activity	Methodologies
Advanced Development Plan	Module
Analyses	Options
Baseline	Requirements
Configuration	Schedule
Cost	Trades
Data Requirement	

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## 1.0 INTRODUCTION

Subject matter presented in this document is in response to and satisfies (in conjunction with Volume II) Data Requirement (DR) 15, "Final Study Report" under Contract NAS8-36526. The contents included herein provide a narrative summary of the activities, trades, analyses, costing exercises, methodologies, technical approaches and studies that were either implemented during Phase B or were products of the Space Station study and conceptual design effort. Study results and conclusions derived from the Phase B study effort will be presented in Volume II, "Study Results."

### 1.1 Scope

Contents provided herein constitute submittal of Volume I of the Final Study Report in accordance with DR-15.

### 1.2 New Huntsville Facilities

The Space Station Program is a large and complex endeavor involving direct participation of several NASA centers with support from the remaining centers. Phase B activity has also included support from several prime contractors and an array of subcontractors.

The Space Station schedule for Phase B has been very aggressive. Major activity has been geared toward selecting a baseline configuration for the station.

In view of this environment, it was necessary that the relationship between NASA and its contractors be very close. It was important for Boeing to have a clear understanding of the Marshall Space Flight Center (MSFC) and NASA objectives and approaches. Such an understanding required daily contact and involvement over an extended period. Furthermore, the maturing nature of the program and its requirements dictated that this contact be

continual. Changes in detailed requirements, new accommodations for customer requirements and cost trades among program alternatives should realistically be expected to continue into Phase C/D.

Due to these considerations, Boeing made the commitment to establish a permanent high tech facility in Huntsville, Alabama, and locate its program team there. This produced the following advantages to MSFC and NASA:

- a. Shortened lines of communication and improved personal working relationships.
- b. Decreased program cost and increased program flexibility due to a more complete understanding of customer, program and user requirements.
- c. Reduction of cost and lost time from travel.
- d. Increased time available for coordination and communication.
- e. Maximum use of the MSFC test facilities and involvement of MSFC personnel during hardware and subsystem development.

In addition to our facilities in Huntsville, we accessed the total capability of The Boeing Company, as required, for developmental shop fabrication, laboratory tests, technology, design support, related Independent Research and Development (IR&D) and research contracts.

### 1.3 Staffing

Boeing concentrated its staffing efforts on placing qualified personnel in positions

corresponding to the individuals background and experience. Management positions were filled by managers familiar with NASA programs and projects. Much of the Huntsville force was brought from Boeing, Seattle, from the group of experienced space program personnel there. When on board, each individual was assigned to tasks most applicable to his or her qualifications. Boeing aligned its organization to respond to the SS Program and incorporated flexibility to facilitate realignment when required.

#### **1.4 Design and Development Phase Planning**

This section presents the Boeing approach to organizing, managing, and accomplishing the Design and Development Phase for WP-01.

##### **1.4.1 Management Relationship to NASA**

Our organizational structure supports the NASA and contractor team effort needed to meet the objectives of the Space Station Program. Throughout the C/D phase, we anticipate many panels and committee meetings to examine and resolve program definition and interface resolution issues. Our organizational alignment supports this approach because it facilitates communication between MSFC and Boeing counterparts, and follows the hardware and project organization of the WBS.

##### **1.4.2 Management Relationships To Tasks**

During the design and development phase, the concept to be employed will be techni-

cal management by module or element task. Each element of the management structure will be organized in a manner that will allow point-to-point contact with MSFC and will accommodate the element management concept. Design Package Teams (DPT) will be a concept employed during Phase C/D. These teams will be headed by appropriate design and functional managers who will assure overall tasks and design integration. Formal policies and procedures that outline and control this concept, including authorization of design and data requirements responsibilities will be implemented. Configuration management functions such as change management will support the appropriate NASA baseline levels but will be organizationally structured to accommodate the element and DPT management concepts. Communication will be emphasized and facilitated by this concept.

##### **1.4.3 Compliance**

Data covering compliance with development phase plans and schedules can be found in the deliveries under DR-10 which are listed below.

- a. Project Implementation Plan:  
D483-50020-1
- b. Productivity Plan: D483-50014-1
- c. Safety Plan: D483-50075-1
- d. Reliability Plan: D483-50075-2
- e. Quality Assurance Program Plan:  
D483-50075-3

## 2.0 SUMMARY OF SIGNIFICANT ACHIEVEMENTS

Submittal of Data Requirements, fabrication of hardware, Advanced Development, and other related activities such as development of the Hatch/Latch are representative of Phase B accomplishments. This section provides a summary of these and other accomplishments.

### 2.1 Data Requirements

Boeing has responded to all Data Requirement delivery schedules and corresponding technical requirements in a timely and efficient manner.

### 2.2 Advanced Development

Design and development of experimental hardware, (such as the ECLSS Four Bed Molecular Sieve) which will lay the ground work for the development of Space Station subsystem components has played a major role in the Phase B study effort. A summary of that effort is included herein.

#### 2.2.1 Initial Elements ADP

Initial Advanced Development Hardware was identified in the Phase B contract. This list formed the basis for the Advanced Development Plan, Data Requirement 05, submitted subsequent to contract award. The plan included detailed task schedules and development criteria and requirements for all identified ADP hardware. The plan has been kept up to date as changes to the requirements and/or hardware have been identified.

#### 2.2.2 AD Implementation for Initial Space Station Program

The Advanced Development program was kicked off in a timely manner subsequent

to Contract Start Date (CSD). Boeing responded to the task by building an advanced development hardware laboratory. Qualified Boeing personnel were assigned to the ADP effort and dedicated their expertise and time to the task. The effort has continued to play a major role in the conceptual design phase and Boeing expanded the ADP operation in the new facilities located at the Jetplex. Table 2.2-I provides a list of ADP hardware as it exists at the time of this submittal.

#### 2.2.3 AD Recommendations and Plan for Growth

Conclusions, recommendations and plans for further development are provided in Volume II, Study Results.

### 2.3 Related Activities

#### 2.3.1 Common Module Prototype

Early in the concept phase of the Space Station Program, Boeing engaged in an effort directed toward design and fabrication of a module structure prototype. The task was initiated to establish a basis for design and process evaluations as well as to provide manufacturing and cost data for use in the Phase C/D proposal effort.

The fabrication concept proposed included the use of the Variable Polarity Plasma Arc (VPPA) welding equipment and associated tooling. The project, a joint effort with NASA/MSFC in their Productivity Center, was set up to use parts fabricated by various vendors which could be structurally assembled in-house (Building 4707 at MSFC) using the VPPA welding process. Structural material selected for the task was aluminum alloy 2219.

**TABLE 2.2-I ADVANCED DEVELOPMENT HARDWARE**

Subsystem	Hardware
Data Management	<ul style="list-style-type: none"> <li>• Sensor Devices</li> <li>• Power Supply Switches</li> <li>• Test Box (Packaging, Hardware Interfaces)</li> </ul>
ECLSS	<ul style="list-style-type: none"> <li>• Multifiltration Test Unit</li> <li>• Reverse Osmosis Test Unit</li> <li>• Urine Pretreat Test Unit</li> <li>• Vapor Compression Distillation Unit</li> <li>• Molecular Sieve Test Unit</li> <li>• CO2 Liquefaction Component</li> <li>• Static Feed Electrolysis</li> <li>• Bosch Reactor System</li> <li>• Water Quality Test Unit</li> <li>• Remote Control Switch Unit               <ul style="list-style-type: none"> <li>1-20A Switch</li> <li>3-50A Switches</li> </ul> </li> <li>• Loads Control Panel</li> </ul>
Thermal Control	<ul style="list-style-type: none"> <li>• Heat Pipe Radiator Panel</li> <li>• External Heat Exchangers (3)</li> <li>• Accessory Package (Pumps, Valves, Tube, Fittings, etc.)</li> <li>• 2-Phase NH3 Test Facility (Refrig. Sys.)</li> </ul>
Manned Systems	<ul style="list-style-type: none"> <li>• MPAC Element Demonstrator:               <ul style="list-style-type: none"> <li>Programmable Switches</li> <li>IBM PC/AT w/Graphics Display and Disk Storage</li> <li>CRT's</li> <li>Hand Controllers</li> </ul> </li> </ul>
Propulsion	<ul style="list-style-type: none"> <li>• Minimum Spill Disconnect</li> </ul>
Structures and Mechanisms	<ul style="list-style-type: none"> <li>• Common Module Wall Configuration Samples</li> </ul>

Working relationships established with MSFC during this effort have proven to be positive. Support provided by the various subcontractors has been timely and deserves commendation. In conclusion, efforts associated with the task have been worthwhile and can be best evaluated by visiting Building 4707 at MSFC and viewing the assembled structure.

### 2.3.2 Hatch/Latch Development

In support of Boeing's Phase B activity, development of a prototype hatch test article was initiated. This test program was initiated in order to investigate hatch design and latching concepts in light of requirements for a pressure capability from either side of the hatch.

This hatch prototype is currently undergoing testing and has already given us new insight to the problems of developing a lightweight hatch stiff enough to meet our present design requirements. The test fixture developed for the hatch can be used to test any number of hatch concepts and for qualification of the final design.

### 2.3.3 Umbilical Development

Current Space Station requirements mandate that connections for hazardous gases and liquids be external to the pressurized volume. In order to minimize EVA time for connection of these fluid lines to the logistics modules, an automated umbilical design has been investigated. This has led to the fabrication of an umbilical test article that has proven that an external auto-

mated umbilical is a feasible way of performing these connections without requiring crew EVA.

### 2.3.4 Common Module Mockup

Early in the program, Boeing dedicated a common module mockup design team to evaluate the design feasibility of the module structure. Simple mockup design (cardboard) was implemented in Seattle. A Full-Scale structural mockup is currently housed at the Boeing Jetplex Facility in the Consolidated building. The mockup has provided needed visibility in the evaluation of module structural design and will continue to support the conceptual design cycle.

## 2.4 Technical Management and Information System (TMIS)

TMIS is an electronic data documentation, transmittal and information system. The concept is an innovation that has been implemented on the Space Station Program. Eliminating a total paper environment is its main goal along with providing quicker response time and improved technical coordination capabilities. Boeing has demonstrated the TMIS concept by electronically transferring intergraph CAD/CAE, datasets, documents, and databases to and from MSFC and established an electronic mail interface (PROFS) with MSFC. Boeing has also electronically demonstrated the transfer of integrated text and graphics from Boeing Huntsville to Boeing Seattle using the Sun/KEEPS workstation.

### 3.0 SUMMARY OF STUDY EFFORT

Dynamic conceptual design development, response to changes in requirements and the performance of trades and analyses have been key elements of the Phase B study effort. This section provides a narrative summary of the Systems Engineering and Integration tasks and WP-01 elements that make up the Space Station system. Detailed results for elements defined below are contained in Volume II, Study Results.

#### 3.1 Systems Engineering and Integration (SE&I)

Defining the system and allocating requirements to configuration items are prime tasks essential to baselining a configuration. A brief synopsis of the SE&I effort for accomplishing this task is included herein.

Methodology incorporated was to support definition and integration of WP-01 end items and provide data to support Space Station definition, planning and the establishment of system and interface requirements and traceability. Performance of trade studies and analyses, cost and technical performance measurements, support of technical reviews and working groups and integration of contract tasks into the system definition and WP element and subsystem design also played major roles in the SE&I effort. The logic network for the task described above is depicted in Figure 3.1-1.

Trades and analyses were conducted concept options investigated and design to cost and technical performance measurement completed. Systems integration allocated, controlled, and made change recommendations on all requirements. Using the design team approach, input from task interfaces were integrated into the requirements. Study products, including plans for software, automation and robotics and growth were provided per the SE&I plan schedule.

##### 3.1.1 SE&I Plan

Boeing's SE&I effort followed and basically conformed to the Level B SE&I Plan included in the Phase B contract. Data Requirement 19, Time Phased SE&I Products, contains detailed products of the SE&I effort, including Engineering Master Schedules (EMS) development, rationale and themes.

##### 3.1.2 Requirements Development

Support to the requirements development effort has involved the generation and/or review, evaluation and submittal of recommended changes to the various requirements documents produced during Phase B. This section provides a synopsis of the effort involved in generating these requirements documents peculiar to WP-01 and essential in supporting requirements definition.

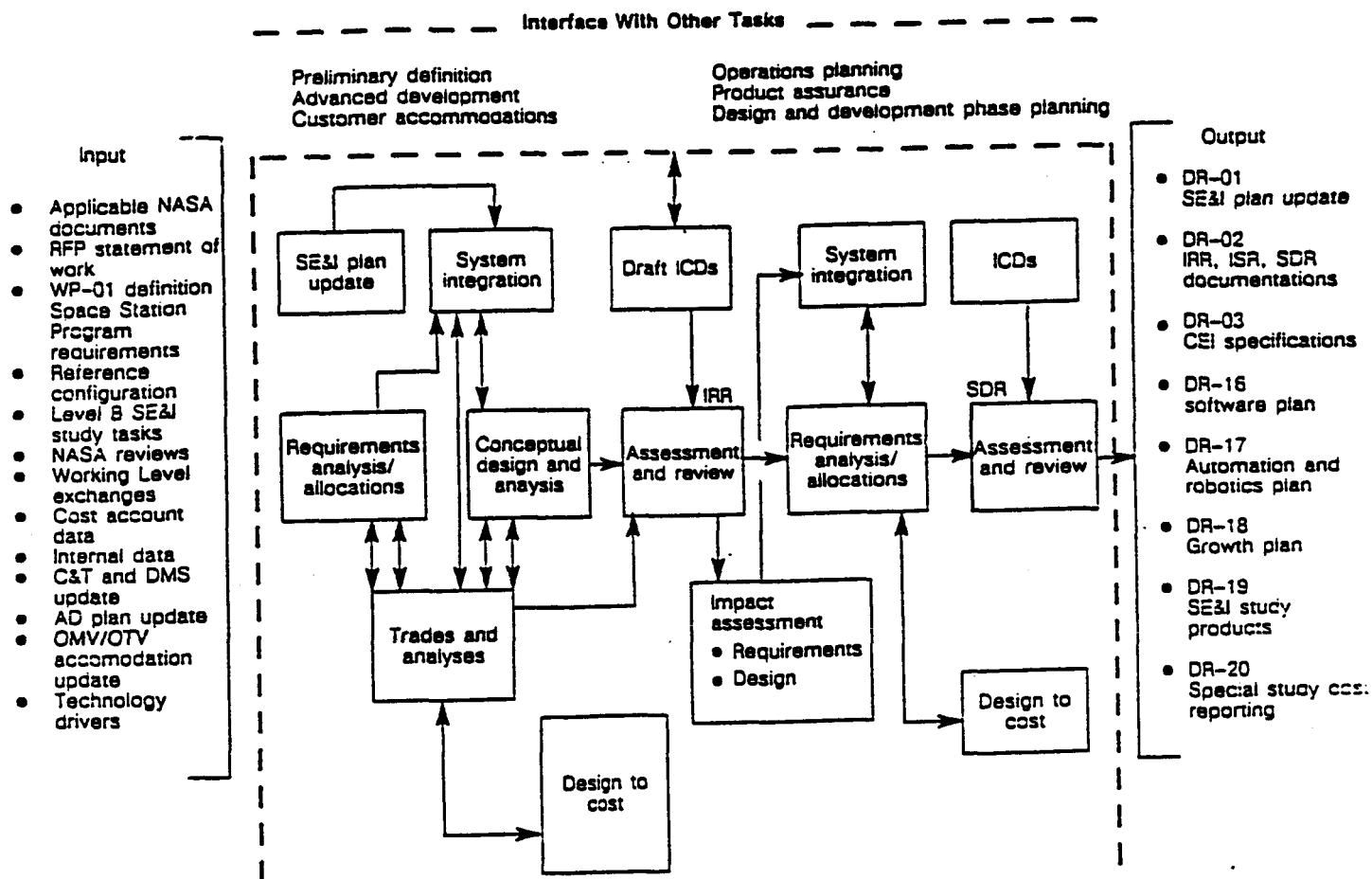


FIGURE 3.1-1 LOGIC NETWORK FOR SYSTEM ENGINEERING AND INTEGRATION

### 3.1.3 Interface Requirements Development (IRD's)

Interface Requirements Documents were prepared in order to document and define the external interfaces existing between Work Packages. The effort was accomplished and delivered in accordance with Data Requirement (DR) 02. Conclusions and results of the interface requirements task will be included in the January (EOC) delivery.

### 3.1.4 System Requirements Document (SRD)

The Systems Requirements Document, which can be considered as a system segment document was prepared in order to baseline WP-01 requirements. These requirements were established and documented in order to form the basis for the WP-01 end item requirements contained in the Part 1 Contract End Item Specifications. The document was generated by MSFC, while Boeing provided complete support in its review and evaluation.

### 3.1.5 Contract End Item Specifications (CEI's)

The production of the CEI's was accomplished and delivered in accordance with Data Requirement 03. A CEI specification was written for each designated WP end item. The documents were baselined and revised as necessary to accommodate WP realignment, changes in requirements and/or other miscellaneous revisions.

### 3.1.6 Man Tended

Man Tended requirements for the Space Station were evaluated and an option study performed in accordance with provisions levied by the Phase B contract. The results of this study have been docu-

mented in accordance with DR-20, Special Study Cost Reporting.

### 3.1.7 Automation and Robotics

Congress (Public Law 98-371) established a requirement that the Space Station Program study the development and application of advanced automation technology not in use on existing spacecraft. In response to this public law NASA formed the Advanced Technology Advisory Committee (ATAC). This committee was tasked to provide NASA with recommendations as to promising areas of development in Automation and Robotics (A&R) and to report their findings to Congress. These recommendations were used as guidelines in the development of the Space Station Automation and Robotics Plan.

As part of the ATAC effort, BAC strongly supported and contributed to the work of the University and Industry Panel, lead by the California Space Institute (Calspace), which provided A&R candidate recommendations and technology evaluations. In fact, BAC's noncontractual volunteered support provided significant additional study breadth, especially in the area of operator systems interfaces. Additionally, our independent technology assessment provided the ATAC invaluable support in their recommendations.

### 3.1.8 Space Station Evolutionary Growth

A study was performed to define a growth station, develop a methodology for attaining this station, and identify the hardware scars required at Initial Operational Capability (IOC) to support the defined growth.

The first step was to define the full operational capability (FOC) station. This included an assessment of the various elements and requirements which could

change during the evolutionary growth from the IOC station. The deltas resulting from this growth were then identified. From these configuration parameters, a block change scenario was developed, which resulted in the initial identification of the required IOC scar.

### 3.1.9 Software Development

The central objectives of the Software Support Environment (SSE) are the production of less expensive and more reliable software – and in less time than has historically been the case. It must be emphasized that the production of software involves an integrated discipline ranging over the entire product lifetime, from requirements to retirement of the programming system. The discipline must be described, encouraged and ultimately enforced by an appropriate Software Engineering program consisting of standards, procedures and tools – as well as a programming and managerial workforce trained in the effective use of the relevant parts of the program.

The standards and procedures under which software development occurs are, in many ways, the most critical of the Software Engineering program elements mentioned. These will detail a set of administrative and technical policies and constraints under which the programming task must take place. Errors, particularly in the critical requirements and design phases, are detected both earlier and more reliably in such environments. Thus, productivity is consequently greater than under the historic rather free-form process.

### 3.1.10 Customer Accommodations

Accommodating customers for commercial use of space will be one of the major drivers and challenges of the Space Sta-

tion Project. The term “customer” is defined as any agency which expresses an interest in the use of the stations’ micro-gravity facility.

### 3.1.11 Test and Verification

The test and verification study effort included establishing guidelines, requirements and conceptual planning for system design verification, hardware verification, Space Station Systems verification and the documentation requirements for implementation of the verification program. The System Test and Verification Plan, DR-04, generally addresses the configuration of the station discussed in section 3.2 of this volume.

### 3.1.12 Product Assurance

During the conduct of the Phase B study, consideration of safety, reliability and quality was included in all engineering assessments. Appropriate evaluations to assure reliability and safety were made.

#### 3.1.12.1 Preliminary Safety Analysis

The Safety Analyses were performed to evaluate systems assigned to WP-01. The analyses were performed on the functions to be accomplished by the hardware and software of WP-01 elements and systems, and included consideration of their interfaces with other WP's. Also included were the WP-01 operations required to assemble the Space Station into the Initial Operational Configuration (IOC).

Although WP-01 operations of a generic sort have been analyzed, the detailed sequence of assembly operations has yet to be established. Therefore, a complete preliminary operational hazard analysis on Space Station assembly into the IOC has not yet been conducted.

### 3.1.12.2 Failure Modes and Effects Analysis

Failure Mode and Effect Analysis (FMEA) results provide information for identifying single failure points, formulating redundancy strategies, designing caution and warning systems, defining maintenance requirements, and spares provisioning; and providing confidence on risk acceptance decisions.

Implementation of FMEA activities during the definition and preliminary design effort, helps in formulating design requirements early in the program thus avoiding costly redesigns in subsequent program phases.

## 3.2 Conceptual Design

Boeing has conducted a study effort geared toward the WP-01 elements of the Space Station configuration. Space Station modules and their various subsystems, propulsion, and OMV/OTV accommodations have made up the bulk of the WP-01 study effort. Although Boeing has concentrated its efforts on WP-01 elements, we have also made significant inputs to the overall system definition, such as major design analyses essential to baselining the Dual-keel configuration.

Preliminary definition of WP-01 elements was provided at Contract Start Date by the Phase B contract. This section provides a brief synopsis of the WP-01 elements. Results produced during the study effort corresponding to each element are contained in Volume II, Study Results.

### 3.2.1 Common Module (Core)

Design and analyses of the common module (core) and its subsystems has been a key element of the WP-01 study effort. Satisfying the requirement to provide a habitable and workable environment for

Space Station Crew members on a continuous basis is one of the great challenges facing our engineering design force. Although definition of the common module has changed along with the evolution of the configuration, its basic definition still holds as that of a pressurized module providing continued life support and communication subsystems which in turn, provide a living and working environment in space. The following subsystems make up the common module (core).

- a. Data Management System
- b. Electrical Power
- c. Communications and Tracking
- d. Structure and Mechanisms
- e. Thermal Control System
- f. ECLSS

### 3.2.2 Environmental Control and Life Support System (ECLSS)

ECLSS in the basic life support for the Space Station the system will provide atmospheric pressure and composition control, module temperature and humidity control, atmospheric revitalization, water management, waste management, extra-vehicular activity (EVA) support, fire and contamination monitoring and control.

### 3.2.3 Laboratory Module Outfitting

Initial definition of the Laboratory Module was to provide an enhanced workable environment geared toward accommodating the major materials and technology and life science experiments essential to the Space Station Program. To do this, necessary outfitting or enhancement of the basic module support systems would have to take place. Design trades and analyses pertinent to this WP element definition

have been an integral segment of the study effort.

### 3.2.4 Logistics Module

The Logistics Module would provide a physical means of an on board and/or transport storage module to accommodate the logistics requirements for supplying and resupplying the Space Station. Analysis of this element resulted in the following definition.

#### 3.2.4.1 Pressurized Carrier(s)

Pressurized Carrier(s) shall be provided for transport of cargo requiring pressurization and shall contain distributed subsystem utilities and equipment to provide functional capabilities as required.

#### 3.2.4.2 Unpressurized Carrier(s)

The unpressurized carrier(s) shall be designed to transport cargo which does not require a pressurized environment.

### 3.2.5 OMV/OTV Accommodations

The Space Station Phase B Contract contained general operational and servicing requirements for the accommodation of Orbital Maneuvering and Orbital Transfer Vehicles. OMV was initially defined to be used at IOC and the OTV was defined as an FOC requirement.

#### 3.2.5.1 OMV Accommodations

The initial station will have an OMV that will be used to deploy and retrieve free flying payloads and to perform in situ servicing using OMV kits.

#### 3.2.5.2 OTV Accommodations

The Space Based OTV at the FOC station will transfer payloads to and from higher energy orbits.

#### 3.2.5.3 Smart Front End (SFE)

Preliminary definitions for the Smart Front End was that of a modular system consisting of a robotic manipulator ORU carrier and resupply modules which would be used as part of the overall vehicle accommodation system. The purpose of incorporating SFE on the SS is to reduce OMV propellant and EVA costs. The module system will be able to handle the total servicing requirements of most satellites defined to date.

### 3.2.6 Propulsion

Initial definition for the propulsion system provides for the attitude maintenance and backup attitude control function for the Space Station. Preliminary configuration definition consisted of the propulsion tankage, propellant, plumbing and thruster systems required to provide the stated functions.

#### 3.2.7 Airlocks

The airlock system provides an effective and safe means for transfer of men and equipment between pressurized and unpressurized zones.

##### 3.2.7.1 EVA Airlock

In addition to the above definitions, the airlock will be man rated and will inter-

face with Extravehicular Mobility Units (EMU). Extravehicular Excursion Units (EEU) and other hardware required for Extravehicular Activity (EVA).

#### 3.2.7.2 Hyperbaric Airlock

In addition to the above requirements and provisions, the Hyperbaric airlock will be used for treatment of decompression.

#### 3.2.8 Interconnect/Nodes and Tunnels

This element provides the structure and mechanisms for module attachment and/or module-to-module attachment at the station and, if appropriate, provide for NSTS berthing.

#### 3.2.9 Habitation Module

This module will provide the required habitable volume for the Space Station crew including the eating, sleeping, rest and relaxation, health maintenance, personal hygiene and work activity accommodations.

### 3.3 Operations and Planning

Operations and planning ground rules, assumptions, requirements and preliminary planning are defined in Data Requirement 07, Operations Planning. Philosophies are discussed under which prelaunch activities, orbital operations maintenance, logistics, resupply and recycle operations would be defined and implemented.

#### 3.3.1 Prelaunch and Postlanding

The Space Station Prelaunch Operations Plan, for WP-01 describes the conceptual approach for prelaunch preparations at the Kennedy Space Center for the WP-01

hardware elements of the Space Station Program. Hardware elements include the outfitted U.S. Laboratory Module (USL), Logistics elements, propulsion subsystem, and station accommodations for the Orbital Maneuvering Vehicle (OMV) and the Orbital Transfer Vehicle (OTV).

#### 3.3.2 Orbital Operations Approach Planning

The Orbital Operations Plan for Space Station, for WP-01 describes present concepts and configurations for on orbit station assembly, outfitting and integration activities and the ground mission support operations anticipated for the orbital operation phase.

#### 3.3.3 Logistics and Resupply Approach Planning

This particular area of operation planning is also documented as part of DR-07. The corresponding plan describes the conceptual approach, organization, management and methods by which on-orbit maintenance requirements will be satisfied and integrated into the total Space Station support system.

#### 3.3.4 On-Orbit Maintenance Approach Planning

The plan corresponding to this topic is included as part of DR-07. The plan describes the conceptual approach, organization, management and methods by which logistics activities will be integrated into a total Logistics, Resupply and Recycle System to maintain a modular craft stationed in low earth orbit.

## 4.0 COST ESTIMATING METHODOLOGY SUMMARY

Cost is and will be one of the major drivers of the Space Station design. Commonality, protoflight and design to cost are some of the major cost reduction concepts being implemented or evaluated for use on the Space Station Program. This section provides a summary of the methodology and modeling tools implemented during Phase B to develop Space Station Program cost data and analysis.

### 4.1 Cost Estimating Methodology

The methodology used to obtain the cost estimates contained in DR-09, "Design, Development and Operations Phase Costs Document," were primarily developed by utilizing parametric approaches; however, the parametric or PCM Model input work sheets were prepared and completed by the individual subsystem engineers who are responsible for the design. In this context, Boeing utilized parametric techniques from a "grass roots" or "bottom-up" approach.

The paragraphs that follow discuss the basic description of the Parametric Cost Model (PCM), the PCM model inputs, the output from the model representative Cost Estimating Relationships (CERs), and/or other factors and relationships used to round out the total program cost estimate.

#### 4.1.1 PCM Model Description

The primary tool utilized for the development of our estimates was the Boeing developed PCM, and other parametric models (i.e., RCA PRICE 'H' and 'S'). The PCM is designed specifically for advanced system estimating. PCM develops cost from the component level "number" data and builds upward in a building-block approach to obtain total program costs. Costs are estimated from physical

hardware descriptions (e.g., weights, design and material complexities) and program parameters (e.g., quantities, learning curves and integration levels). The fundamental PCM working unit is "manhours," which allows relationships that tie physical hardware descriptions first to design engineering or basic factory labor and then on through the organizational structure to pick up such functional areas as system engineering test and development.

PCM estimating relationships are based on statistical correlations of previous Boeing history. Physical hardware descriptions are correlated with the internal model working logic and each major functional area (e.g., project engineering developmental shop and system tests, etc.) is presented and integrated in the model.

The accuracy of our estimating approach is a function of (1) input quality, (2) capability to handle customer program conditions, and (3) inherent model accuracy. One of the primary tools associated with the development of these cost estimates is the Boeing developed weight statements. Detailed component weights are calculated from, and in conjunction with the cost model reference description.

Engineering and Manufacturing work on a real-time basis with the estimating system to support design decisions based on judgment. As trade studies advance, design detail will increase. The models are formulated to accept increasing amounts of detail as the design evolves, enabling a more accurate estimate. The ability to handle real program conditions is guaranteed by using PCM to integrate the total acquisition estimate. PCM is structured to be sensitive to varying program conditions such as design approaches and subcontracting philosophy. It can also incorporate

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a broad range of specific hardware features such as design complexity, the use of off-the-shelf hardware, test level, hardware integration level, WBS organization and production automation.

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